

# THE WEATHER AND CIRCULATION OF DECEMBER 1960<sup>1</sup>

## An Unusually Cold Month in the United States

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### 1. HIGHLIGHTS

Average temperatures throughout most of the contiguous United States during December 1960 underwent a marked reversal from the warm regime which had dominated the fall season [1, 2]. Subzero temperatures were frequent in the northern half of the country east of the Rocky Mountains, and freezing temperatures threatened winter vegetable and citrus crops from southern California eastward through the Rio Grande Valley to central Florida.

Snow cover, which had been restricted to the eastern slopes of the Rockies and extreme northern Plains, spread throughout the northern half of the country early in December and for the most part remained throughout the month. In the southern Plains, precipitation in excess of normal resulted in some flooding around mid-month, while drought conditions in the Great Basin which had been alleviated somewhat in November resumed during December.

### 2. THE GENERAL CIRCULATION

The general circulation at 700 mb. for December 1960 (fig. 1) represented a distinct change from the predominantly zonal or high-index state of the preceding month [1], particularly in the western portion of the Northern Hemisphere from western Europe to the central Pacific Ocean. A comparison of figure 1 with the mean 700-mb. height pattern for the preceding month shows that the diffuse planetary wave system of November became resolved into a series of well-defined troughs and ridges located in climatologically preferred areas [3].

The field of anomalous 700-mb. height changes (changes after the normal change has been removed) from November to December (fig. 2) helps delineate the areas of greatest amplification. The greatest change, +680 feet, took place in the central Atlantic with the development of the Azores High at a higher than normal latitude. This was associated with a northward shift of the mean westerlies and subsequent deepening of the downstream trough in the eastern Mediterranean where anomalous heights fell by 310 feet (fig. 2). The 5-day mean charts (not shown) show that amplification of the wave pattern of the gen-

eral circulation apparently began with the rather sudden development of the Azores High late in November. Subsequently this amplification seems to have spread upstream, first to western North America and then to northeastern Asia.

Relatively little change occurred in the eastern part of the hemisphere except in northeastern Asia. Nearly all of Asia was dominated by a vast Siberian High at sea level, extending from the Black Sea to Japan (fig. 3). Generally stormy conditions existed in Europe and the Mediterranean area, but the modifying effects of maritime air did not penetrate beyond European Russia.

### 3. THE INDEX CYCLE

The change in the westerly circulation from November to December was a classic example of an index cycle as described by Namias [4, 5]. Figure 4 shows the march of indices of temperate ( $35^{\circ}$ – $55^{\circ}$  N.) and subtropical ( $20^{\circ}$ – $35^{\circ}$  N.) westerlies at 700 mb., as defined by overlapping 5-day mean maps computed three times per week. The index referred to here is for the western half of the Northern Hemisphere from  $0^{\circ}$  to  $180^{\circ}$  W. The temperate westerlies reached a peak near the end of the third week in November and then began a four-week decline before making a rapid recovery late in December. The dotted line, giving the daily components of the mean index, is included to show the very sharp drop in the index which is damped somewhat by the averaging process and coincided with the first of several severe storms in the Southwest. The decline in the temperate latitude index was accompanied by southward displacement of the westerlies except in the North Atlantic, so that the subtropical index rose as rapidly as the zonal index fell, reaching a peak December 21, a day after the minimum in the temperate index.

Although there seems to be a strong preference for index cycles to occur in late winter, they are not uniquely fixed with respect to month. One necessary condition for the onset of an index cycle seems to be an abundant supply of cold air in polar regions. Figure 5A shows that the 1000–700-mb. thickness for November averaged 130 feet below normal in northwestern North America, thereby satisfying this condition. However, in order to maintain the atmospheric heat balance, the containment of polar

<sup>1</sup>Articles describing the weather of January, February, and March 1961 will appear in the April, May, and June 1961 issues, respectively, of the *Monthly Weather Review*.



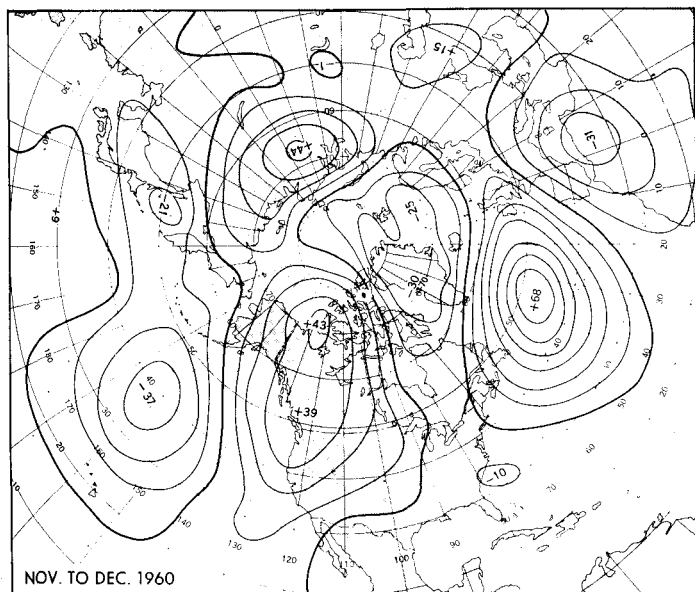


FIGURE 2.—Difference between monthly mean 700-mb. height anomalies for November and December 1960 (December minus November) in tens of feet. Anomalous rises in western North America and falls in the east were associated with amplification of the long-wave pattern.

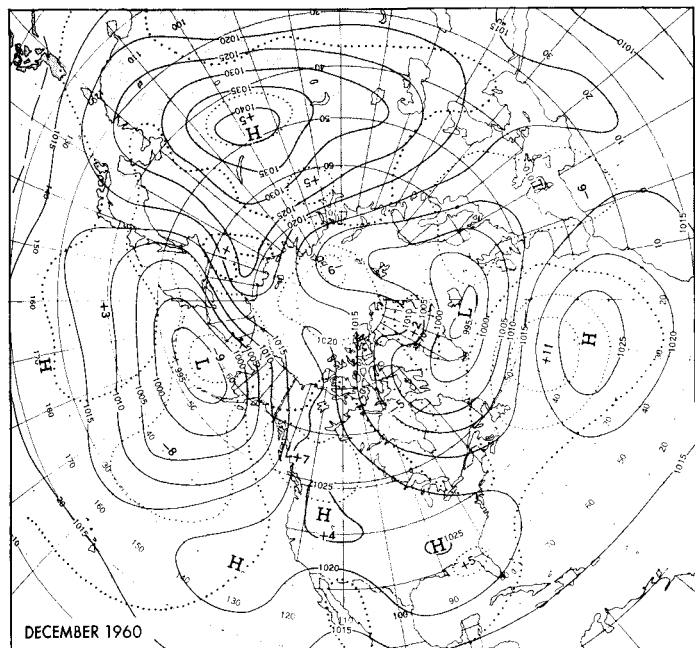


FIGURE 3.—Average sea level pressure (solid lines) and its departure from normal (dotted lines) in millibars for December 1960. High pressure was accompanied by cold weather in the contiguous United States.

distributed uniformly across the nation, 78 percent decreased in average temperature by at least one temperature class (out of five classes) from November to December (fig. 6A). Of the remaining 22 percent, only 3 percent increased. Even in the area of no change or increase,

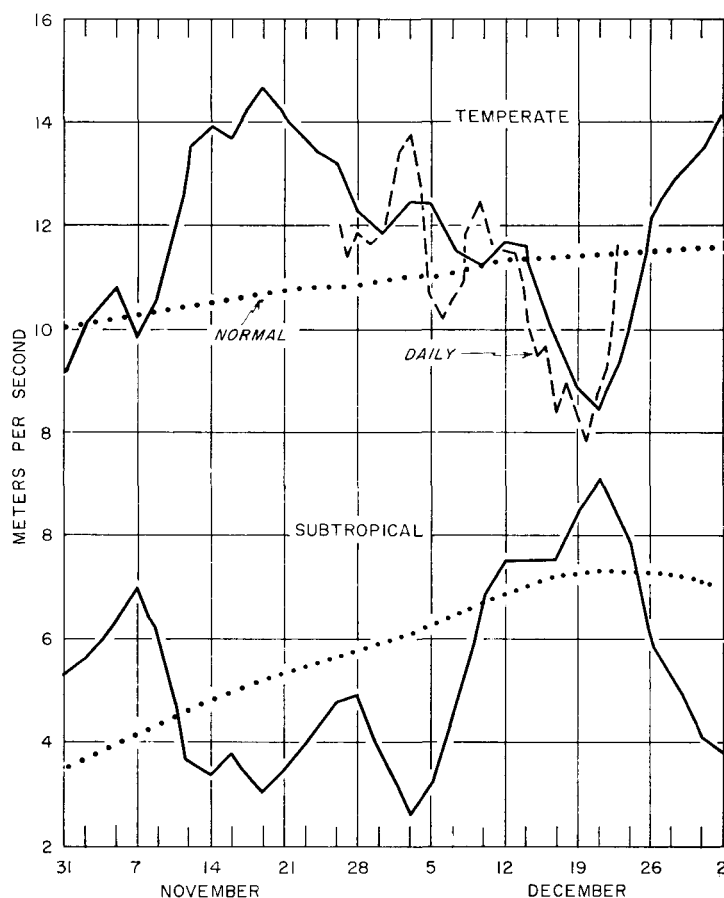


FIGURE 4.—Time variation of 5-day mean 700-mb. indices in meters per second for the western zone of the Northern Hemisphere from 0° to 180° W. Temperate index applies between 35° and 55° N., and subtropical index between 20° and 35° N. Values are for 5-day periods ending on dates indicated. The dashed line represents a daily index, and the dotted lines are the normals based on the data of Weather Bureau *Technical Paper No. 21*.

only in the extreme northern Plains were temperatures above normal for December.

The Great Basin area and California remained cool under the influence of large stagnant anticyclones. In spite of abundant sunshine, record daily minimum temperatures in the cool dry air mass kept mean temperatures below normal. An interesting effect of these persistent Basin Highs was reported from Boise, Idaho, where the average wind speed was only 4.6 m.p.h., the lightest in 21 years.

The most unseasonably cold part of the country was the East and South as far west as Arizona (fig. 7). Figure 8A shows the trajectory of migratory anticyclones carrying cold air masses from Canada just west of the Great Lakes and through the Ohio Valley. Throughout the area from the Mississippi Valley eastward some record daily minimum temperatures were established along with record low temperatures for the month, such as  $-9^{\circ}$  F. at three

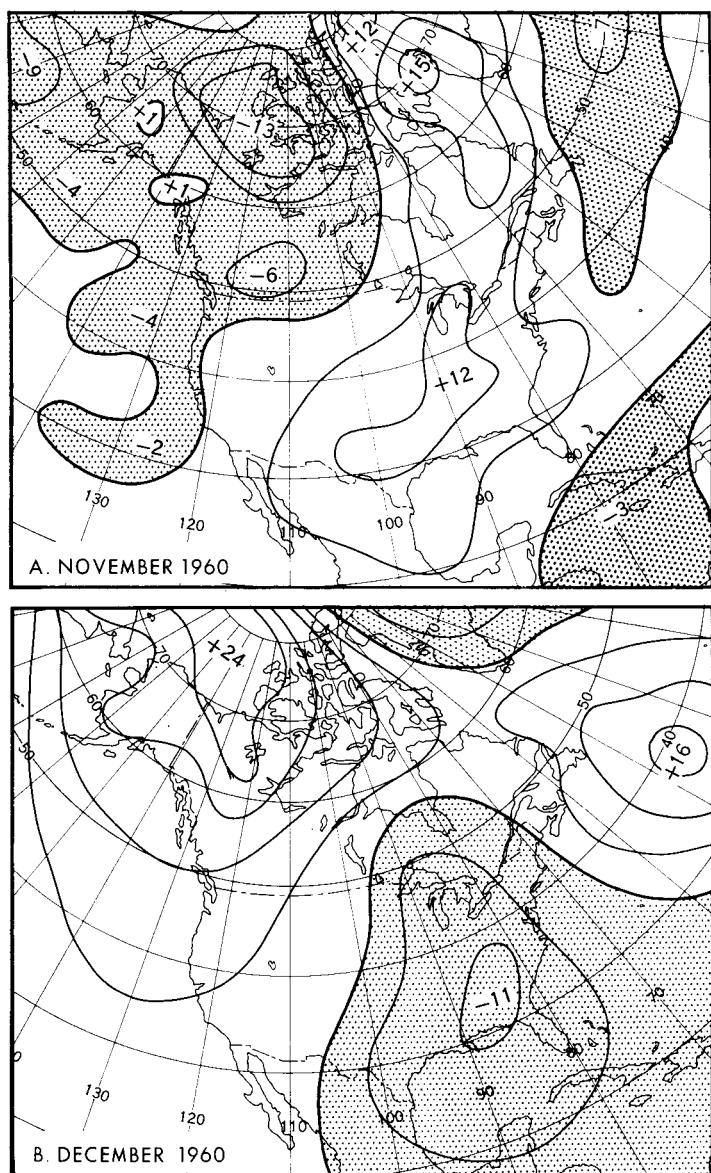


FIGURE 5.—Mean departures from normal of 1000–700-mb. thickness for (A) November 1960 and (B) December 1960, both in tens of feet. Note the complete reversal in phase as the index cycle progressed.

stations in Kentucky and  $-7.5^{\circ}\text{F.}$  at Evansville, Ind. For most stations, average December temperatures were the lowest in from 10 to 25 years and close to record intensity. In Florida, freezing temperatures threatened citrus and vegetable crops as far south as Tampa on five occasions. Richmond, Va. reported December 1960 as the only month on record with every daily minimum temperature below  $32^{\circ}\text{F.}$

In the lower Mississippi Valley and Southern Plains anticyclonic conditions prevailed at sea level (fig. 3), chiefly emanating from Great Basin Highs. However, there was also some contribution from polar air masses, as evidenced by subfreezing temperatures in the Rio Grande Valley and resultant crop damage.

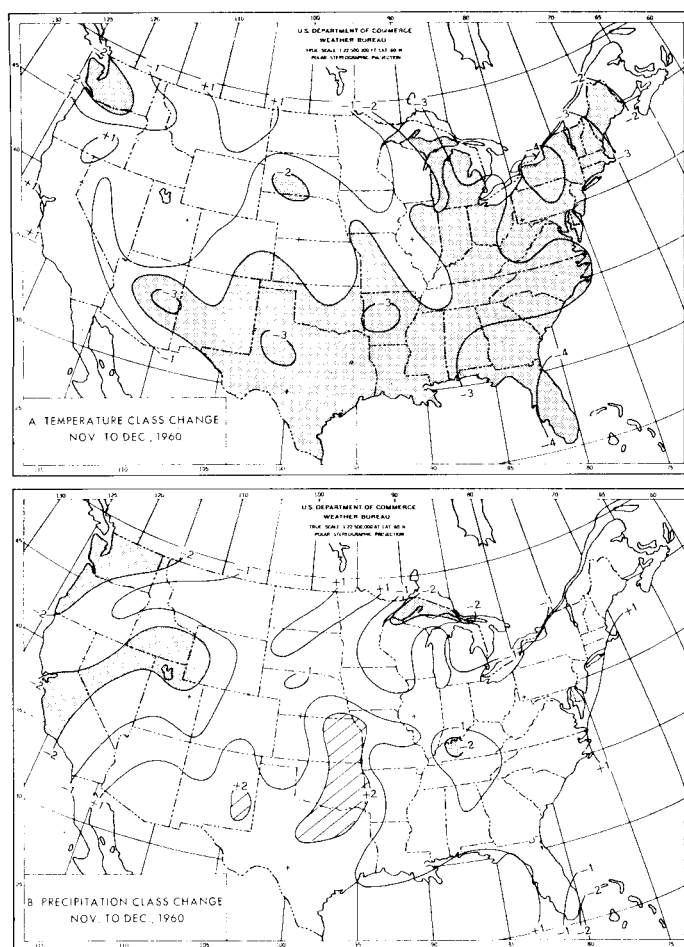


FIGURE 6.—(A) The number of classes the anomaly of monthly mean temperature changed from November to December 1960, and (B) the number of classes the total precipitation category changed from November to December 1960. Areas of positive change greater than two classes are hatched, and areas of negative change greater than two classes are stippled.

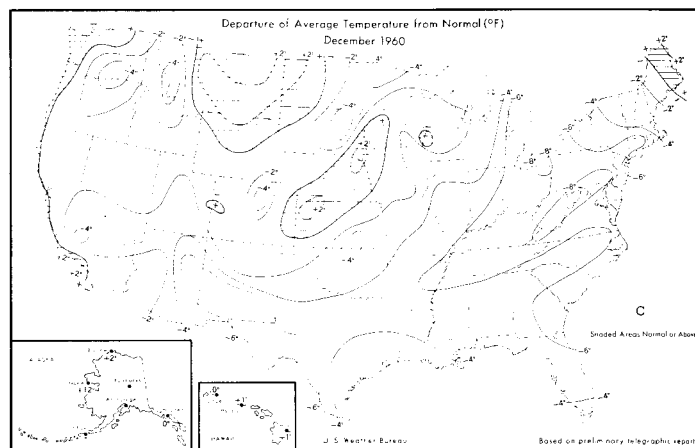


FIGURE 7.—Temperature departure from normal ( $^{\circ}\text{F.}$ ) for December 1960 (from [6]). Widespread cold was associated with circulation shown in figures 1 and 3.

Below normal temperatures in Arizona and New Mexico were maintained by persistent cloudiness due to cyclonic conditions aloft (fig. 1) which were quite pronounced during the first three weeks of the period. In addition, heavy snows early in the period probably contributed to lower than normal temperatures. Late in the month a warming trend began in the Southwest, coincident with the rising zonal index.

While new records for daily minimum temperature were common throughout most of the country, warm air in advance of a severe storm in the central Great Plains produced record high maximum temperatures in the Northeast near the end of the first week in December.

The amplification of the trough-ridge system in the eastern Pacific and western North America, which provided the mechanism for bringing cold air into the contiguous United States, was also responsible for the warmest December on record for most of Alaska. A strong anomalous southerly component of the average flow, shown by the height anomaly pattern in figure 1 (coincident with the sea level isobars, fig. 3), produced an influx of warm maritime air throughout most of the month. The extent of the exchange of air masses is well illustrated by the change in the 1000–700-mb. thickness charts for November and December (fig. 5).

### 5. PRECIPITATION

In general, excessive precipitation in the contiguous United States was restricted to the central third of the country and to the North Atlantic coast (fig. 9). An unusual feature of December's precipitation regime was the large amount of snowfall occurring so early in the season. In the Southwest and the Northeast many new monthly snowfall records were established, such as 10 inches at El Paso, Tex., and Winslow, Ariz., 17 inches at Dayton, Ohio, and 21 inches at Worcester, Mass. Moderate amounts were reported elsewhere except for the Great Lakes and most of the Great Basin where representative stations such as Lansing, Mich., and Salt Lake City, Utah, reported their driest Decembers on record. In contrast, Waco and Dallas, Tex., reported the wettest December on record.

It is interesting to compare the precipitation patterns for November [1] and December in terms of high and low index circulations. November's pattern was wet in the west and relatively dry east of the Rocky Mountains—a pattern often associated with fast westerly flow. However, in December amplification of the ridge in western North America and deepening of the upstream trough produced a strongly meridional steering current aloft, and the westerlies were weaker than normal throughout the West (fig. 10). The intensity of the western ridge was great enough to block effectively the passage of migratory cyclones from the west (fig. 8B), so that the Pacific Northwest during this low-index regime received from 25 to 50 percent less precipitation than normal, and the Great Basin received less than half of normal. On the other

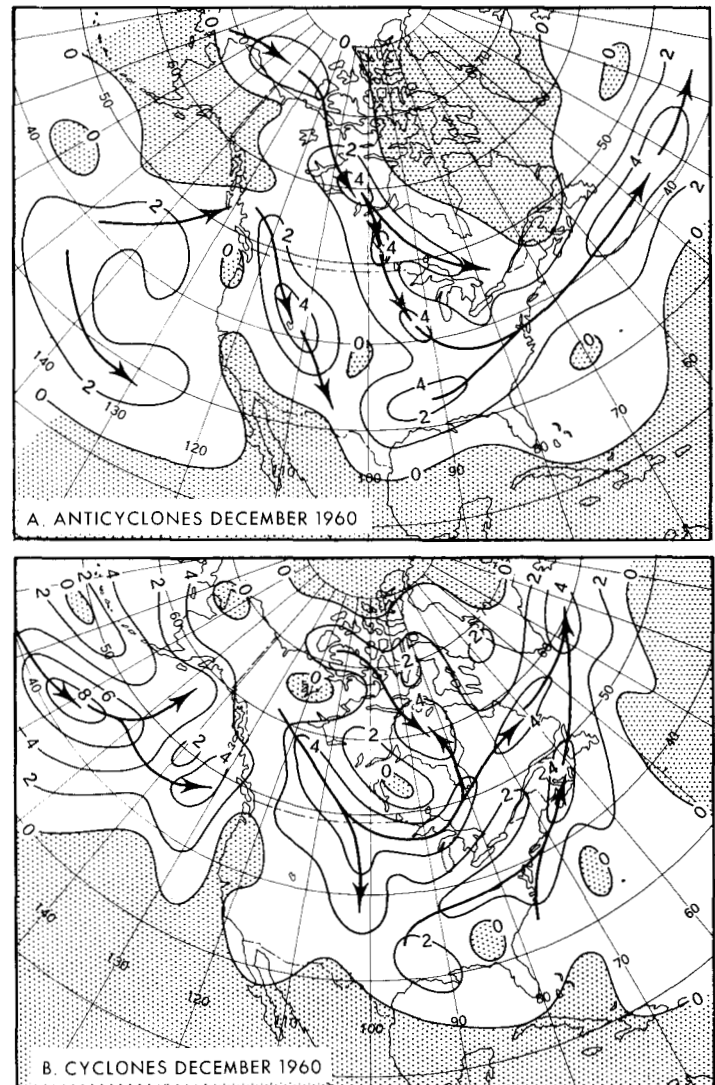


FIGURE 8.—Number of (A) anticyclone passages and (B) cyclone passages (within equal-area quadrilaterals of 66,000 n. mi.<sup>2</sup>) during December 1960. Primary tracks of migratory sea level systems are indicated by solid arrows. Areas of zero frequency are stippled.

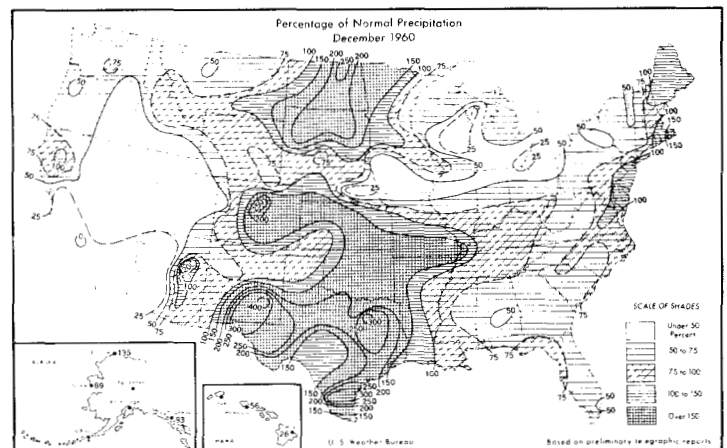


FIGURE 9.—Percentage of normal precipitation for December 1960 (from [6]). Amounts were generally in excess of normal between the Mississippi River and the Continental Divide but deficient elsewhere.

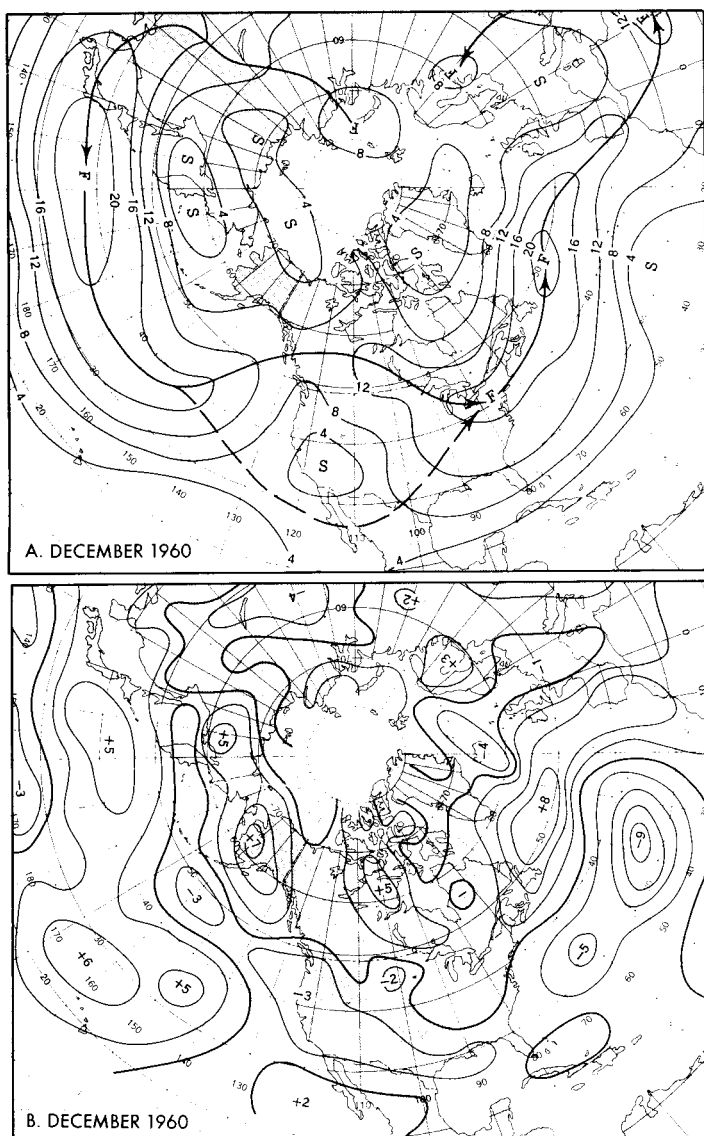


FIGURE 10.—(A) Mean 700-mb. isotachs in meters per second for December 1960. Solid arrows indicate primary axes and dashed arrows secondary axes of maximum wind speed. (B) Departure from normal of mean wind speeds for December 1960 (in meters per second). Weaker than normal westerlies were associated with wet weather in the Great Plains and dry weather west of the Continental Divide.

hand, the weakness of the westerlies diminished foehn drying and favored upslope precipitation in the Plains region between the Mississippi River and the Continental Divide (fig. 10B).

Another common feature of low-index circulations is the presence of areas of mid-tropospheric confluent flow at fairly low latitudes such as that found in the Texas area (fig. 1). While this was not an unusually strong confluent zone, there was sufficient contrast between cold and warm air masses to lead to three major storms in the southern Plains and up to 400 percent of normal precipitation with some flooding in eastern Texas and southern Arkansas. These same storms produced heavy snows as they moved through the Ohio Valley, roughly along the track shown in figure 8B. They were responsible for record December snowfalls from northern Virginia through New England as they deepened in the area east of the mean trough near the Middle Atlantic coast (fig. 1).

Figure 6B illustrates well the general change from the precipitation regime of November to that of December; that is, from wet to dry in the West, a general increase in the Plains States, and little change elsewhere. While it has been mentioned that November had a typical high-index precipitation pattern, December's pattern was not necessarily typical of low index since distribution of precipitation is dependent on the precise geographical location of the quasi-stationary trough and ridge systems, which can exhibit considerable variation during periods of low index.

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